Safe human machine interaction and personalised worker assistance for adaptative workplaces

Madeira 26 September 2018, Angelo Marguglio (ENGINEERING)
1. Project overview

2. Human-factor dimensions

3. A4BLUE Methods & Tools

4. Use case scenario

A4BLUE: Adaptive Automation in Assembly FOR BLUe collar workers in Evolvable context

FOF-04-2016: Continuous adaptation of work environments with changing levels of automation in evolving production systems

Duration: 01/10/2016 – 31/09/2019
Budget: 4.179 M€
1. To **develop** and **evaluate** a new generation of **sustainable, adaptive** workplaces dealing with **evolving requirements** of manufacturing processes (i.e. short & long term changes);

2. To introduce **automation mechanisms** that are suitable for **flexible** and **efficient task execution** in **interaction** with human workers and by optimising **human variability** through **personalised** and **context aware assistance** capabilities as well as **advanced human-machine interfaces**.
Project overview: Specific objectives

1) **Adaptability**: by providing an open, secure, configurable, scalable and interoperable adaptation management and assistance system (A4BLUE adaptive framework) that allows effortless integration of heterogeneous hardware and software components and is able to adjust the behaviour of workplace parts according to changes;

2) **Interaction**: by providing a set of safe, easy to use, intuitive, personalised and context aware multimodal human-automation interaction mechanisms;

3) **Sustainability**: by providing methods and tools to determine the optimal degree of automation of the new assembly processes that combine and balance social and economic criteria to maximize long term worker satisfaction and overall performance.

New or enhanced automation mechanisms
Plug & Produce Capabilities
A4BLUE adaptive framework including assistance tools
Multichannel interaction mechanisms including AR
Method & Tool for the definition of the optimal degree of automation
Method & Tool for assessment of worker satisfaction
Usability methodology
Assessment framework
Project overview: A worker centred approach

Context aware interaction and Personalised assistance

- Safe Human-Automation collaboration
- Human-Automation multi-channel interaction
- Automation adaptation
- On the job training & guidance
- Decision support
- Knowledge management

Iterative Safety and Security Risk Assessment

Usability Worker satisfaction
1. Do not re-invent the wheel

2. Alignment with the main RAs in Smart Manufacturing
Safe Human-Automation collaboration

Introducing automation mechanisms in collaboration with humans creates new challenges.

Safety

Security and Privacy

Enabling adaptation to workers characteristics and context involves the processing of personal data.

A4BLUE introduced in the design phase both privacy/security by design and safety by design concepts supported by an iterative risk management process to identify potential risks and countermeasures, considering most common regulation and standards.
Human-Automation multi-channel interaction

- Verbal and non-verbal interaction to communicate the appropriate commands (H2M).
- Visual and auditory mechanisms to provide feedback (M2H).
Context aware interaction and Personalised assistance

• Based on FIWARE OCB and part of FIWARE for Industry ecosystem
• Publish-Subscribe broker supports context information exchange among all the A4BLUE components
• Entity definition based on the A4BLUE Events Taxonomy
• CEP analyses context and trigger appropriate adaptive reactions, adapting the A4BLUE overall behaviour to the recognized person/product/process
VRStar provides immersive VR/AR simulation.

- **AR and VR Clients**: Front-end applications able to render a 3D scene and collect user inputs
- **Instructor Station**: A graphic control panel for the master node
- **Scene Editor**: A graphic editor of the context maps, their actors and properties
- **Third party Manager**: Bidirectional communication channel with external and remote components

https://vimeo.com/a4blue
On the job training & guidance

Each step of the guidance is represented and showed to the operator in the form of a 2D floating holographic panel.

Voice commands and gestures represent the main input source for an AR application.

The actions and physical movements to perform on-field for a given procedure are shown by virtual animations using holograms.

Thanks to Spatial Mapping system and the Room alignment procedure, the AR elements are constantly tied with the real world in real time.
Decision support

Methodology and web tool to define the Optimal Level of Automation (LoA)

- **Core Module**: Analysing and structuring of the process
- **Constraint Module**: Finding and setting of limits of the automation
- **Cost-based Module**: Determination of the optimal LoA, regarding costs
- **Worker Satisfaction Module**: Optimal LoA, considering worker satisfaction
- **Proposed Automation Module**: Suggest an LoA for the determined process, taking cost and satisfaction into account
- **Analyse**: Plan, prepare and implement measures to get to the suggested LoA

**Intervention requests and DSS**

- **Intervention requests** (e.g. collaboration, maintenance, inspection)
- **Decision support dashboards**
Knowledge management

- Fostering the cooperation and the **human-oriented management of information**
- Providing social networking tools and services, enabling formal and informal support (e.g. tips, best practices, …) and **training services** (e.g. lesson learned, certification, …)
- **Full integration** with A4BLUE RA (CAM, EM, AR, DSS, …)
- Supporting various challenges identified in **industrial scenario** (i.e. CESA and AIRBUS)
Usability and Worker satisfaction

Development of evolvable user-centred automated work systems to promote worker satisfaction within A4BLUE:
• Usability design methodology and assessment
• Operator satisfaction model integration
• Personalised adaptive automation analysis
• Psychometric tool for the assessment of worker satisfaction

Other experiences from partners:
• Task analysis and decomposition
• Mental workload impact analysis
• Worker acceptance and training needs analysis
• Procedural vs tacit knowledge / skill analysis
• Comparison of mental workload and usability across different devices
Adaptive Automation in Assembly
For BLUE collar workers satisfaction in Evolvable context
Adaptive framework including Plug & Produce capabilities, assistance tools and multichannel interaction

Reference Architecture + Reference implementation ➔ 4 Use case applications (HW & SW components)

Methods for the introduction of adaptive automation and worker satisfaction

Method for the definition of the optimal degree of automation
Method for assessment of worker satisfaction
Usability methodology
Use case application: AIRBUS UC scenario

**Scenario**: complex hydraulic system assembly, quite manual and comprising various sets of operations including a lot of different parts to be installed in constraint positions.

**Objective**: a more optimized hydraulic system assembly through automation and Virtual/Augmented Reality.

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<thead>
<tr>
<th>Actors</th>
<th>Automation Mechanisms</th>
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<tbody>
<tr>
<td>Assembly operator</td>
<td>Smart Torque Wrench</td>
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<td>Quality supervisor</td>
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**Main motivation**: to evaluate the impact of an adapted AR HMI in terms of performance and error rate for different skilled groups of people and to enable full quality assurance approach and operators performance thanks to traceability.
Use case application: AIRBUS UC alpha results

A4BLUE AIRBUS UC alpha scenario:
Use case application: CESA UC scenario

**Scenario**: deburring operation (completely manual in the AS IS situation)

**Objective**: to incorporate a robot to assist the worker in the deburring operation

**Motivation**: to increase the quality and efficiency of the process as well as the ergonomic conditions of the worker by reducing the most exhausting manual work (100 min less).

**UC1 Auxiliary process**

**Scenario**: main landing gear retraction actuator assembly process which is fully manual and it is supported by a large amount of technical instructions in PDF. Furthermore the training process is time consuming and must be performed on periodic basis as the certification expires.

**Objective**: to incorporate AR based guidance providing the right information to the worker at the right moment based on operator’s profile as well as collaborative knowledge management tools supporting knowledge sharing between workers.

**Motivation**: to reduce operators training time, to reduce the time spent by the operator reviewing documentation and to increase confidence, participation, and internal communication among the personnel.

**Actors**
- Deburring operator; Maintenance operator; Assembly operator; Workshop supervisor; Quality supervisor

**Automation Mechanisms**
- Collaborative deburring robot
Use case application: CESA UC alpha results
Scenario: Collaborative assembly of a latch valve in a fenceless environment, including the preparation activities, final inspection and transport of the finalised part to the warehouse as well as maintenance activities.

Main motivation: Evaluate trust, usability and worker satisfaction (in terms of safety, interaction, ergonomics, assistance, etc.).
Use case application: IK4.TEKNIKER UC alpha results

Context-awareness
Integration with legacy system (MES)

Automation adaptation
Automatic execution
Personalised ergonomic adaptation

Safe H-A collaboration
Safe coexistente in a fenceless environment

H-A multi-channel interaction
Multimodal interaction - Natural speaking and gestures: START, RESUME, STOP task

Decision support
Intervention request: collaboration, maintenance, inspection – Decision Dashboard

A4BLUE IK4-TEKNIKER UC alpha scenario: http://a4blue.eu/video-ik4-tekniker/
Use case application: RWTH UC scenario

**Scenario:** final assembly of electric vehicles, focusing on handling, adjusting and joining as well as on the auxiliary processes of picking, documentation and information provision. Furthermore, it involves the provision of the required tools by means of an automated tool trolley (TT).

**Objective** to incorporate AR based guidance right information to the worker at the right moment based on operator's profile and to provide the tools required for the assembly by means of an automated tool trolley.

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<td>Automated tool trolley</td>
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<td>Maintenance operator</td>
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<td>Production supervisor</td>
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<td>Production planner</td>
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**Main motivation:** improving worker satisfaction, reducing training time, improving process efficiency by reducing errors in the picking activity; improving ergonomics, reducing non-added value working time and validating a tool to determine the optimal degree of automation.
Use case application: RWTH UC alpha results

A4BLUE RWTH UC alpha scenario: http://a4blue.eu/the-video-on-rwth-scenario-is-out/

Tool-Trolley Features:
- Free navigation
- M2M-Communication via OPC UA
- Long-range steering via voice commands
- Gesture steering for short-range